Course Title: **Radiological Control Technician**
Module Title: **Contamination Monitoring Instrumentation**
Module Number: **2.17**

Objectives:

2.17.01 List the factors which affects an RCT's selection of a portable contamination monitoring instrument.

⇒ 2.17.02 Describe the following features and specifications for commonly used count rate meter probes used at your site for beta/gamma and/or alpha surveys:
a. Detector type
b. Detector shielding and window
c. Types of radiation detected/measured
d. Energy response for measured radiation
e. Specific limitations/characteristics

⇒ 2.17.03 Describe the following features and specifications for commonly used count rate instruments used at your site:
a. Types of detectors available for use
b. Operator-adjustable controls
c. Specific limitations/characteristics

⇒ 2.17.04 Describe the following features and specifications for commonly used personnel contamination monitors at your site:
a. Detector type
b. Detector shielding and window
c. Types of radiation detected/measured
d. Energy response for measured radiation
e. Operator-adjustable controls
f. Specific limitations/characteristics

⇒ 2.17.05 Describe the following features and specifications for commonly used contamination monitors used at your site (Tool, bag, laundry monitors).
a. Detector type
b. Detector shielding and window
c. Types of radiation detected/measured
d. Energy response for measured radiation
e. Specific limitations/characteristics

References:

1. "Radiation Detection and Measurement," Glenn F. Knoll, 1979.
2. "Basic Radiation Protection Technology," Daniel A. Gollnick, 1988.
3. "Operational Health Physics," Harold J. Moe, 1988.
4. ANSI N323A
5. (Various Manufacturers Technical Manuals)

Instructional Aids:

1. Overheads
2. Overhead projector/screen
3. Chalkboard/whiteboard
4. Lessons learned

I. MODULE INTRODUCTION

A. Self-Introduction

1. Name

2. Phone number

3. Background

4. Emergency procedure review

B. Motivation

Environmental monitoring plays a large role in the field of radiological control. Environmental monitoring is used to estimate human population doses, determine the impact a site has on the environment, monitor for unplanned releases as well as quantifying planned releases, and gives us data useful in determining pathway data.

C. Overview of Lesson

1. Environmental monitoring goals

2. Principles of program design

3. Radiological control responsibilities

4. Analysis of environmental samples

5. Site environmental monitoring methods

6. Transport mechanisms

D. Introduce objectives

O.H.: Objectives

II. MODULE OUTLINE

NOTE: The text is provided for some commonly used instruments. The site must adjust text as necessary for instruments used at each site. Text added for specific instruments used at the site must, at a minimum, cover material required by the objectives.

A. General Discussion

1. Measurements using portable contamination monitoring (count rate) instruments provide the basis for assignment of practical contamination and internal exposure controls.

2. To establish the proper controls, the contamination measurements must be an accurate representation of the actual conditions.

3. Measurements using non-portable contamination monitors, such as an Eberline PCM-1B or PM-6 are used to identify personnel contamination prior to exiting controlled areas or facilities. Hand and shoe monitors are used by some sites.

4. Measurements using counter scalers to determine the levels of transferrable contamination on specific location samples are the basis for contamination postings and material releases from controlled areas.

5. Many factors can affect how well the measurement reflects the actual conditions, such as:

   a. Selection of the appropriate instrument based on type and energy of radiation, radiation intensity, and other factors.

   b. Correct operation of the instrument based on the instrument operating characteristics and limitations.

   c. Calibration of the instrument to a known radiation field similar in type, energy and intensity to the radiation field to be measured.

   d. Other radiological and non-radiological factors that affect the instrument response, such as radioactive gases, mixed radiation fields, humidity and temperature.

B. Factors Affecting Instrument Selection

Objective 2.17.01

1. The selection of the proper instrument is critical to ensure the data obtained is accurate and appropriate.

2. Instrument selection is based on the characteristics and specifications for that instrument as compared to the required measurements.

3. Several factors should be considered when selecting the instrument.

   a. The type of radiation to be measured

   b. The energy of the radiation to be measured

   c. The intensity of the radiation (dose rate or activity levels)

d. Interference from a mixed radiation field

e. Background radiation conditions

f. Environmental factors, such as radioactive gases or temperature, affecting instrument response

g. Procedural requirements

4. To ensure the proper selection and operation of instruments, the instrument operator must understand the operating characteristics and limitations of each instrument available for use.

C. Count Rate Meter Hand Probes

Objective 2.17.02

1. EBERLINE MODEL HP-210 AND VICTOREEN MODEL 110C

a. Models like the Eberline Model HP-210 or Victoreen Model 110C hand probes are sensitive beta detectors using a thin window "pancake" Geiger-Muller (GM) detector. These detectors are designed for contamination surveys of personnel, table tops, floors, equipment, etc.

1) Detector responds to alpha, beta, gamma and x-ray radiation of minimum energies.

a) alpha >3 MeV

Detector must be close enough to the source of alpha particles to prevent alpha particle attenuation in the air between the source and the detector.

b) beta >40 keV

This precludes the detection of low energy beta particles, such as the beta particle from the decay of tritium (E_{max}= 18.6 keV.)

c) gamma >6 keV

Photon radiation, such as gamma or x-ray, can interact in the detector walls and the fill gas to create a pulse. However, the probability of interaction is small due to the shallow depth of the detector and therefore the efficiency for photon radiation is small.

Density determines minimum energy response

2). GM tube has mica window of 1.4 to 2.0 mg/cm^2 density.

3) Gamma sensitivity is approximately 3,600 counts per minute (cpm) per mR/hr for Cs^{137}.

4) Available with either high-density tungsten or aluminum housings.

a) HP-210AL - aluminum housing with a low shielding factor for low background use.

Weight of 1.5 lbs.

b) HP-210T - tungsten shield covering the top and sides of the detector allows use in high background area.

Weight of 4.5 lbs.

c) Victoreen 110C - aluminum housing with a low shielding factor for low background use.

5) Victoreen 110C series hand probes are almost identical to the Eberline model HP-210AL.

b. Detector type

1) The detector is sealed Geiger-Mueller (GM) "pancake" detector. A "pancake" detector has a radius or width that is much larger than the depth of the detector.

Halogen absorbs the UV photons from the excited positive ions without ionizing.

2) The shielded hand probe contains the GM detector which has the mica window protected by a wire or stainless-steel etched screen.

About midway of the voltage plateau

3) The fill gas in the GM tube is halogen-quenched argon.

4) The operating voltage for the GM detector is 900V $\pm$ 50V.

5) Detector has 50 μs resolving time which is defined as the minimum time that must elapse after the measurement of an ionizing particle before a second particle can be measured.

Dead time + recovery time = resolving time

c. Detector window and shielding

1) The thin detector window is 1.4 - 2.0 mg/cm^2 mica and is protected by the screen which is 79% open.

May vary with detector type

a) Mica windows must be used instead of Mylar, because the Mylar will react with the halogen quench gas.

b) The window has an effective surface area of 2.4 in^2 (15.5 cm^2).

d. Efficiencies for the detector are dependent on the type and energy of the radiation.

1) The detector is designed, calibrated and used to measure beta radiation.

a) 22% for ^{137}Cs

The numbers vary with probe

b) 16% for ^{60}Co

c) 32% for $^{90}Sr/^{90}Y$

d) 15% for ^{99}Tc

e) 6% for ^{14}C

2) Typically, a conservative beta efficiency of 10% is assigned for these types of problems. Therefore, to convert the cpm reading to a dpm value, the meter reading is multiplied by ten. (dpm = cpm X 10)

3) Efficiencies for alpha and photon radiation are not typically quoted because the probes are not calibrated for either type of radiation. However, gamma efficiencies are low, about 1-2%, because of the shallow detector depth. Alpha efficiencies are highly dependent on the particle energy and distance from the source, but can be as high as 20%.

e. Specific limitations and characteristics

1) Generally, environmental conditions, such as humidity and temperature, do not affect the response of the detector because it is sealed at a pressure slightly less than atmospheric pressure.

2) Use of the hand probe at proper frisking speeds and distances is extremely important to ensure accurate results. The probe should be used at a distance of no more than 1/2" and at a speed of about 1" per second.

results. The probe should be used at a distance of no more than 1/2" and at a speed of about 1" per second.

3) The mica window is extremely fragile and sufficient care must be taken to prevent any punctures which will ruin the detector.

4) The detector probe is not calibrated for alpha radiation; however, it may be used for indication of alpha emission from contamination, if used properly.

2. Victoreen Model 489-4 Detector Probe (THYAC)

a. The Model 489-4 detector probe is a cylindrical GM detector with a sliding beta shield and can be used for high count rate applications of contamination monitoring.

b. Detector

1) The detector is a sealed Geiger-Mueller (GM) cylindrical detector.

2) The shielded probe contains the cylindrical GM tube which has a stainless steel wall surrounding the entire detector volume.

3) The fill gas in the GM tube is halogen-quenched argon.

4) The operating voltage for the GM detector is 900V $\pm$ 50V.

c. Detector window and shielding

1) The detector "window" is the 30 mg/cm^2 stainless steel wall of the detector.

2) Shielding provided by a 360E sliding steel shield.

d. The GM detector will detect any radiation that interacts within the sensitive volume of the detector.

1) Charged particle radiation must pass through the detector wall before an interaction can take place; therefore, the minimum sensitivity for charged particle radiation is based on the wall thickness and distance from the detector.

a) The minimum sensitivity for beta particles is about 200 keV with the shield retracted, which precludes the measurement of most average-energy, fission-product beta particles. The detector will not detect beta radiation with the shield in place.

b) Alpha particles can **<u>not</u>** be detected because all alpha particles would be stopped in the detector wall.

Detector is not calibrated for beta radiation.

2) Photon radiation, such as gamma or x-ray, can interact in the detector walls and the fill gas to create a pulse. The minimum sensitivity for photon radiation is about 6 keV with the shield retracted and about 70 keV with the shield in place.

e. Efficiencies for the detector are dependent on the type and energy of the radiation but are not typically quoted because the instrument ranges are adjusted to read the irradiation field value for the gamma-emitting isotope used during calibration.

f. Specific limitations and characteristics

1) Generally, environmental conditions, such as humidity and temperature, do not affect the response of the detector because it is sealed at a pressure slightly less than atmospheric pressure.

2) When used with a count rate meter, the meter reading (cpm) is converted to a dpm value by multiplying by thirty (dpm = cpm X 30).

3) The detector probe is not calibrated and is not recommended for measurement of beta radiation due to the thickness of the detector wall.

3. Eberline Model AC-3 Alpha Hand Probe

a. The Model AC-3 is an alpha scintillation detector used to identify alpha-emitting contamination.

b. Detector

1) Scintillation detector using ZnS (Ag) powder embedded in tape.

2) Active detector area is 9.1 inch^2 (59 cm^2) within a 5 3/4 x 2 inch sampling area.

Standard PM tube is replaced with less sensitive one

3) Low gamma sensitivity.

c. Detector window and shielding

1) Window is 1.5 mg/cm^2 aluminized plastic film.

2) Total probe assembly is 11½ inches long x 2 3/4 inches wide x 3¼ inches.

3) Clear plastic probe cover is supplied for protecting the detector window.

4) Weight of probe is 1 pound 6 ounces.

d. Efficiency

1) From a 1-inch diameter source or from 50 cm^2 of a large-area distributed Pu-239 source, 2 pi geometry.

a) Minimum efficiency is 28%.

b) Typical efficiency is 31%.

c) Sensitivity to Pu-239 source is typically 2 x 10^7 cpm per microcurie/cm^2.

e. Specific limitations and characteristics

1) Probe is sensitive to gamma radiation.

a) Not used in areas where gamma interference in mR/hr will indicate $\geq$300 cpm alpha.

b) The mr/hr value is affixed to each instrument during routine calibration.

2) Detector window is very fragile. Puncture or damage to covering will cause detector to become sensitive to light. All detector windows must be checked for holes or damage.

3) Erratic meter movement can be due to electrical short in probe connection cable. Checked for damage by rotating probe in a circular motion. If erratic reading is noted, instrument is to be returned to calibration group.

4) Detector is to be held 0.5 cm from the surface and moved at approximately 1-2 inches per second.

D. Count Rate Instruments

Objective 2.17.03

1. Victoreen Model 496

a. Victoreen Model 496 is an analog GM count rate meter.

1) Used in conjunction with GM probe assembles to measure beta and gamma radiation.

a) Victoreen 489-4

Only detector with which meter is calibrated can be used.

b) Victoreen 110-C

c) Eberline HP-210

2) Three operating ranges of 0-800, 0-8,000, and 0-80,000 cpm.

3) Response time of 10 seconds or less to 90% of the final reading.

4) Accuracy of ± 10% normally.

5) Weight of 4 pounds.

b. Operation

1) Meter face readout of 0-800.

2) Rotary switch for power and range functions.

a) off - setting for non-operation

b) batt - initial selection for testing of battery strength, needle will identify battery strength.

c) x1 - establishes meter reading times 1 as the activity in cpm (0-800 range).

d) x10 - identifies meter reading times 10 as the activity in cpm (0-8,000 range).

e) x100 - identifies meter reading times 100 as the activity in cpm (0-80,000 range).

3) Volume control rotary switch

a) Audible indication of count rate by independently controlled speaker.

b) Functions of off and on to control speaker.

4) Correction factors for beta/gamma cpm to dpm reading based on type of detector attached.

a) Thyac 489-4 - meter reading x30.

b) Pancake probes - meter reading x10.

2. Ludlum Model 12

a. The Model 12 is an analog count rate meter

b. Electronic circuitry has potential for use of proportional, scintillation, and GM detectors

c. Available in three different detector configurations. Detector characteristics discussed earlier.

1) Eberline HP-210 detector -used for beta-gamma measurement.

Only detector with which calibrated can be used.

2) Victoreen 110C - used for beta-gamma measurement.

3) Eberline AC-3-7 Probe - used for alpha measurement.

d. Operating ranges of 0-500, 0-5,000, 0-50,000, and 0-500,000 cpm.

e. Fast-Slow toggle switch provides for meter response time selection.

1) Slow - response time of 22 seconds for 90% of final reading.

2) Fast - response time of 4 seconds for 90% of final

f. Operation

1) Meter face readout of 0-500.

2) Range multiplier selector switch is a six-position switch.

   a) OFF

   b) BAT

   c) x1,000

   d) x100

   e) x10

   f) x1

3) Audio on-off switch for operation of count rate speaker.

4) Fast-Slow toggle switch to establish response time of 4 seconds (fast) or 22 seconds (slow).

5) RES button provides a rapid means to reset the meter to zero.

6) HV Test Button displays the detector voltage on the meter when depressed.

7) Operates on two standard "D" cell batteries or rechargeable cells.

8) Weight of 3.0 pounds, less detector and batteries.

3. LUDLUM MODEL 3-6

   a. The Model 3-6 is an analog survey instrument

   b. Electronic circuitry has potential for use of proportional, scintillation, and GM detectors.

   c. Operating ranges of 0-500, 0-5,000, 0-50,000, and 0-500,000 cpm.

   d. Fast-Slow toggle switch provides for meter response time selection.

      1) Fast - response time of 5 seconds for 90% of the final reading.

      2) Slow- response time of 25 seconds for 90% of the final reading.

e. Operation

1) Meter face readout of 0-5,000.

2) Range multiplier selector switch is a six-position switch.

a) OFF

b) BAT

c) x100

d) x10

e) x1

f) x0.1

3) Audio on-off switch for operation of count rate speaker.

4) Fast-Slow toggle switch to establish response time of 5 seconds (fast) or 25 seconds (slow).

5) RES button provides a rapid means to reset the meter to zero.

6) Operates on two standard "D" cell batteries or rechargeable cells.

7) Weight of 3.5 pounds, less detector.

4. Ludlum Model 177-2 Count Rate Meter

a. Placed at specific locations for personnel contamination monitoring

b. Electronic circuitry has potential for use of scintillation, and GM detectors.

c. Available in conjunction with alpha, beta-gamma, and alpha-beta-gamma detection probes.

d. Operating ranges of 0-500, 0-5,000, 0-50,000, and 0-500,000 cpm.

e. Fast-Slow toggle switch provides for meter response time selection.

1) Slow - response time of 22 seconds for 90% of final reading.

2) Fast - response time of 2.2 seconds for 90% of final reading.

f. Operation

1) Meter face readout of 0-500.

2) Range multiplier selector switch is a six-position switch.

a) OFF

b) x1

c) x10

d) x100

e) x1,000

3) Audible click per radiation incident volume control adjustment.

4) Operates on 115 V AC only and does not contain battery pack.

5) RES Button provide a rapid means to reset the meter to zero.

6) Alarm Set Selector Switch is 11 position switch used to select a predetermined alarm threshold (0.5 to 500) at 100 cpm over background. Audible alarm setting of 1,000 Hz preset.

7) Weight of 4.2 pounds, less detector.

E. Personnel Contamination Monitor PCM-1B

Objective 2.17.04

1. Eberline Personnel Contamination Monitor, Model PCM-1B is a microprocessor-based radiation detection system.

2. Performs quick indication of beta-gamma contamination, with option of alpha capabilities.

a. PCM-1B has fifteen (15) independent gas-flow proportional detectors.

b. Control processing unit (CPU) includes an Intel 8085 microprocessor, memory, and input-output lines.

c. Performs two-part personnel whole body survey by performing a right side then left side personnel body survey.

3. Operation mode

a. Monitor measure and stores background values for all detectors.

1) Checks for high background alarm levels.

2) Checks for low or high count failures.

3) Checks for low gas pressure conditions.

b. Ultrasonic motion sensor detects movement of person toward monitor.

1) Background check is suspended.

2) Display reads - "STEP UP - INSERT RIGHT ARM"Red LED flashing light while counting.

c. Placement of arm in arm cavity initiates personnel monitoring routine.

1) Display reads - "COUNTING RIGHT SIDE"

2) Counting continues for duration of specific counting time.

a) If no alarm levels detected, unit beeps and displays clearance.

b) Display reads - "RIGHT SIDE OK -- INSERT LEFT ARM"

d. Placement of left arm in cavity initiates monitoring.

1) Display reads - "COUNTING LEFT SIDE"

2) Counting continues for duration of specific counting time.

a) If no alarm levels detected, unit beeps and displays clearance.

b) Display reads - "COUNT COMPLETE, YOU MAY PASS"

c) Display accompanied by chime and the LED extinguishes.

4. Alarm modes

a. Premature arm withdrawal.

Arm withdrawn prior to preset count time completion.

1) Alarm alert sounds.

2) Display read -"COUNT INCOMPLETE **RECOUNT**"

Explain dead zones and sum zone readouts that may identify these.

3) Reinsertion of arm restarts count.

b. Contamination detection

Activity in excess of alarm levels detected in either right or left side count.

1) Alarm alert sounds at end of count time.

2) Appropriate display appears - "ALARM: ZONE 1 - ZONE 2 - ZONE 3," etc.

3) Alarm and display continue for specified alarm hold time.

4) Alarm stops and display read - "CONTAMINATED -- PLEASE STEP OUT."

5. Trouble Shooting

a. PCM-1B message display will illuminate the trouble or diagnostic lights to identify various monitor malfunctions. Description of basic malfunction conditions listed below.

b. High background - Background count rate in any zone(s) has increased above selected limit.

1) Alarm light, high background light, Sonalert, and "Channel Designation (i.e. 'Zone 1'): High Background" message are activated.

Sonalert - audible alarm.

2) Area should be checked for radioactive sources and/or detector checked for dirt, moisture or radioactive contamination.

Detector can be vacuumed for cleaning.

c. High count fail –

1) Alarm light, trouble light, Sonalert, and channel designation message are activated.

64k count capacity has been exceeded, likely by electronic surge.

2) Count capacity in any zone has been exceeded and PM Group to be contacted for troubleshooting.

d. Low count fail or low sensitivity fail

1) Alarm light, trouble light, Sonalert, and channel designation message are activated.

Detectors in train need to be checked.

2) May be result of component failure or decrease/loss of decrease/loss of counting gas. Detector identified should be checked for leak in mylar.

3) Leak in mylar can be sealed with scotch tape.

e. Contaminated detector -

1) Contaminated detector light is activated along with contaminated detector message. Operation will continue with detector light on.

Note: Monitor should not be used until contamination light has been cleared.

2) Detector to be checked for contamination and decon around detector performed with masslin cloth. Detector area can be vacuumed.

f. Loss of gas pressure -

1) Two cylinders used but cylinder No. 1 used until empty. When empty, "Bottle No. 1 Empty" light activated and No. 2 put in use automatically.

2) If both cylinders fail (empty) the trouble light, "Bottle No. 2 Empty," and display with indicate "Failure**Out of Gas" message will be activated. Total loss of gas, PCM should be turned off and upon gas replacement a 4 hour purge before re-energizing of unit.

6. PCM-1B must not be used to monitor personnel with any

trouble light illuminated. Monitor placed in "out of Service" mode until cause corrected.

F. Eberline PM-6

1. Microprocessor-based radiation monitor using gas-flow proportional detectors for whole body contamination scans.

2. Two basic types of PM-6s are typically used

   a. PM-6A

      1) Uses eleven gas-flow counters to detect beta-gamma contamination.

      2) Same basic operating characteristics as PCM-1B.

      3) Source checked daily using beta-gamma source.

   b. PM-6A-2

      1) Uses fifteen gas-flow counters to detect alpha or beta-gamma contamination.

      2) Four additional detectors used in hand pods to increase ability to detect hand contamination.

      3) Hand and foot detectors sensitive to alpha as well as beta-gamma contamination.

      4) Source checked daily using alpha and beta-gamma sources for both hand and foot detectors. Beta-gamma source is used on body detectors.

3. Source checks and troubleshooting PM-6 is same as PCM-1B.

G. Specialty Contamination Monitors - *(tool, bag, laundry monitors)* — Objective 2.17.05

NOTE: Site must add materials based on other contamination monitors used at the site. Text added must cover, at a minimum, the material required by the objective.

1. Detector type

2. Detector shielding and window

3. Types of radiation detected/measured

4. Energy response for measured radiation

5. Specific limitations/characteristics

III. SUMMARY

A. Review major topics

Review Objectives

1. General discussion/instrument selection

2. Count rate meter probes

3. Count rate meters

4. Personnel contamination monitors

5. Specialty contamination monitors

B. Review learning objectives

IV. EVALUATION:

Evaluation should consist of a written examination comprised of multiple choice, fill-in the blank, matching and/or short answer questions. 80% should be the minimum passing criteria for examinations.